BBC RD 1983/7

BBC

RESEARCH DEPARTMENT

REPORT

ENHANCED UK TELETEXT: experimental equipment for high-quality picture coding and other enhancements

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THE BRITISH BROADCASTING CORPORATION

July 1983

BBC RD 1983/7
UDC 621.397

ENHANCED UK TELETEXT: EXPERIMENTAL EQUIPMENT FOR HIGH-QUALITY PICTURE CODING AND OTHER ENHANCEMENTS

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Summary

A recent Research Department Report [1] described how it would be possible to enhance the basic teletext service, to include facilities for improving its access time and lead up to the inclusion of high-quality still pictures. The present Report describes the construction of a pair of microcomputer-based units which will serve as a research tool in engineering these enhancements: one unit will normally be used as a transmitter and the other as a receiver in a closed-circuit teletext transmission. The microcomputer system and frame store design is basically similar to that currently used by Logica in the Flair electronic graphics equipment.

Considerable effort has been devoted to the development of software handling. The units are equipped with a CP/M operating system, which is already widely known. This greatly simplifies the management of files and includes compiling routines and a software debugging tool. Software is being prepared in PASCAL.

So far routines have been developed to receive, generate, edit and transmit teletext in its present form. Early attention has been given to demonstrating that picture teletext is feasible through a crudely-coded slow-scan television system. Further work will concentrate on establishing an acceptable sampling structure for these pictures and optimising the coding of data to fit in with a hierarchy of coding embracing other aspects of enhanced teletext, for example, geometric drawing, electronic painting and telesoftware. A high quality character font has also been incorporated to improve the display of text.

Issued under the Authority of

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION
July 1983
(PH-253)

It uses SI units in accordance with B.S. document PD 5686.

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1. Introduction

Over the past two years there has been a considerable increase in the interest shown towards broadcast UK teletext by both the customer and broadcast engineer.

A 'National Teletext Month' declared in October 1981 provided a considerable impetus to the popularity of teletext at a time when the mass production of decoders was becoming firmly established. Television receiver manufacturers estimated that there were about 600,000 teletext sets in the UK by the end of 1982 and that this figure is currently increasing at the rate of 40,000 per month. A Research Department Report [1] published in 1980 outlined a number of proposed enhancements to the UK teletext system which extend its scope and capabilities, whilst at the same time maintaining its ruggedness and efficiency. Some of these enhancements are now being broadcast experimentally. They include the provision of a television service data packet which, repeated every second, relates the teletext service to the accompanying television programme and its television network, and also carries the address of the initial teletext page as well as date and time information. Also, included with every teletext page, a teletext page service row of data will contain a 'page check word' to give an indication of the correct and complete reception of its associated page and a series of six or more page addresses which correspond to other teletext pages having some 'link' or 'association' with the page. These page addresses can be selected by the editor of the teletext magazine. A future generation of decoder containing multi-page stores would be able to respond to these additions. In particular the latter facility would allow six 'linked' pages to be captured (and checked for accuracy) and updated if necessary as a result of selecting a single page. This would be one method of decreasing the apparent access time of the magazine.

Further enhancements include extended character sets and improved graphics based on dynamically re-definable characters and the use of geometric and colouring operations. In the limit, the system could deal with photographic quality, high resolution pictures to exploit the full capability of the television display. Any development which causes a widening of the boundaries of the teletext system must ensure that existing teletext sets maintain a compatible service. A similar situation obtained when the radio service was converted to stereo operation and the television to colour.

A teletext decoder capable of handling high-quality pictures is different from the present-day decoder in several respects. At the centre of such a decoder would be a micro-computer to manipulate the thousands of bits of data involved. The storage of a single high-quality picture occupying a full screen area would require hundreds of times more storage than today's decoder. It is the continuing trend of falling costs in microcomputers and semiconductor/disk storage which makes a sophisticated teletext decoder worth considering as an economic domestic product in the years ahead.

At the present time a considerable amount of research and development is required to establish the optimum means to achieve these ends. A programme of work was carried out, under an agreement with the UK Department of Industry, to construct a pair of microcomputer-based units to make these investigations. The units can be configured as the local transmitter and receiver in a closed-circuit situation to simulate an enhanced teletext transmission system. Such a system would, with suitable software developments, be capable of demonstrating and investigating any of the proposed enhancements for data broadcasting, particularly those which involve the output displayed on a conventional television receiver.

An important consideration in this work is the need to involve other broadcasters, industry and British Telecom in order to maintain compatibility with their planned enhancements to teletext and videotex (Prestel). Common areas of interest include display standards and the establishment of an optimum coding hierarchy.

This Report describes the experimental equipment which has been built at Research Department and the approach to the development of software which accompanies it. Some results from the initial experiments to transmit simple picture teletext, as demonstrated in 1981 at the IEEE Chicago Spring Conference and the Berlin

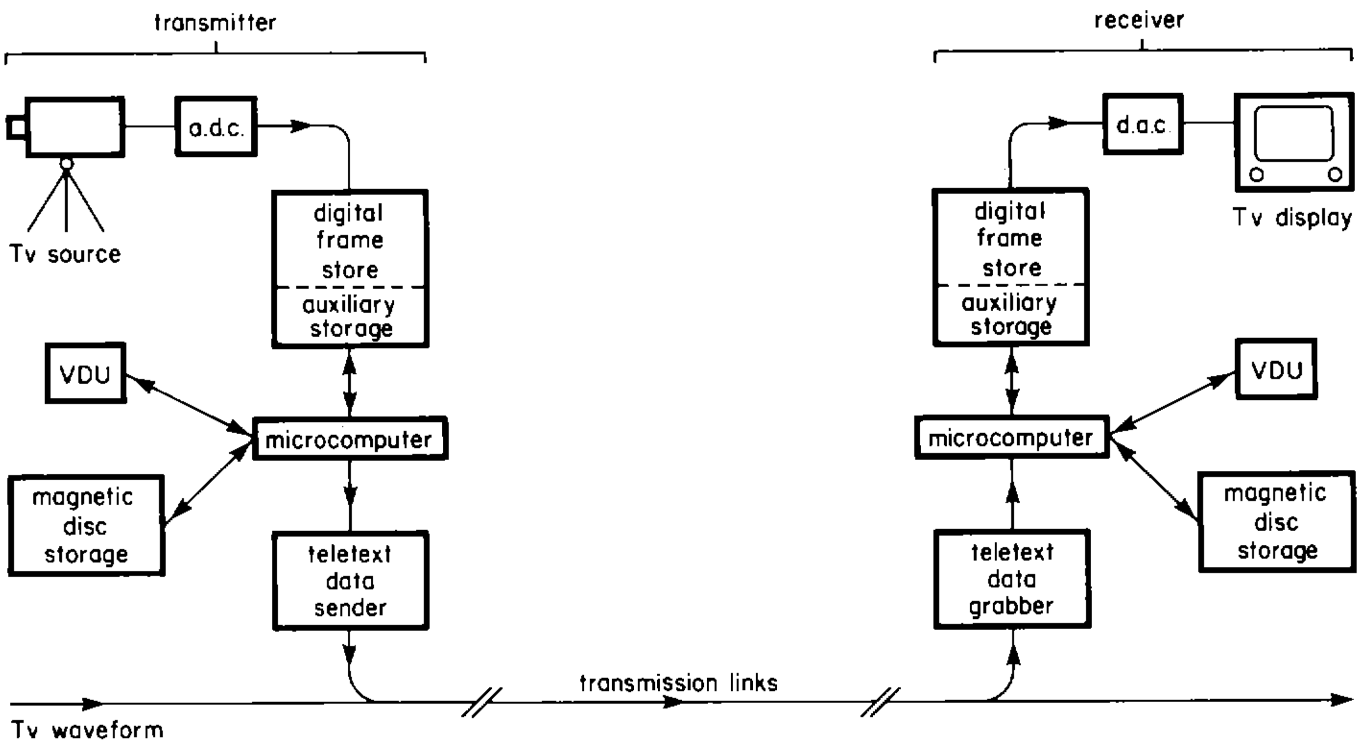


Fig. 1 — Equipment for studying coding methods for enhanced UK teletext.

Radio show are given and the direction in which the work can proceed is indicated.

2. Equipment considerations

A block schematic showing the main requirements of the enhanced teletext experimental equipment is given in Fig. 1. The equipment is considered to be primarily a research tool and an important requirement is that it should be made as general and flexible as possible from the outset. This is achieved by building the design around a microcomputer system. The equipment consists of two units which are shown assembled together as transmitter and receiver but a close inspection reveals that they contain almost identical components. The main difference is that one has the ability to send and the other to receive or "grab" teletext data. If both units were equipped with a teletext data-grabber they could each function as independent teletext decoders capable of monitoring broadcast signals.

The other essential requirement of each unit is a large data store which can hold at least one television frame. To allow any kind of visual image to be portrayed, the frame buffer must be of sufficient capacity to permit access to all picture elements (pixels) of the display device individually. The quality of such images is then limited only by the display device used.

In the transmitter unit, the equipment is configured as an editing suite with the microcomputer visual display unit (v.d.u.) acting as the keyboard control. Simple text can be input and edited directly from the standard "querty" keyboard. Full resolution pictures can be "grabbed" into the frame buffer directly from external sources such as a camera or television slide scanner. The stored image can be modified or processed further under instructions from the keyboard. Intermediate graphics or re-definable characters can be input initially from the keyboard or, more likely, from paper tape or magnetic disk and subsequently stored in a convenient location such as an extension of the frame buffer store. The equipment can also support a graphic tablet as used in electronic graphics composition. At the transmitter the result of all these means of formulating a teletext page is 'coded' and combined with the video signal for transmission.

At the receiver the teletext data is recognised, removed from the video signal and decoded to produce the received visual display. The frame buffer also acts as a character and graphics generator with the keyboard as the receiver control.

Each unit is backed up with magnetic disk facilities for the permanent storage of teletext images and the software routines developed for

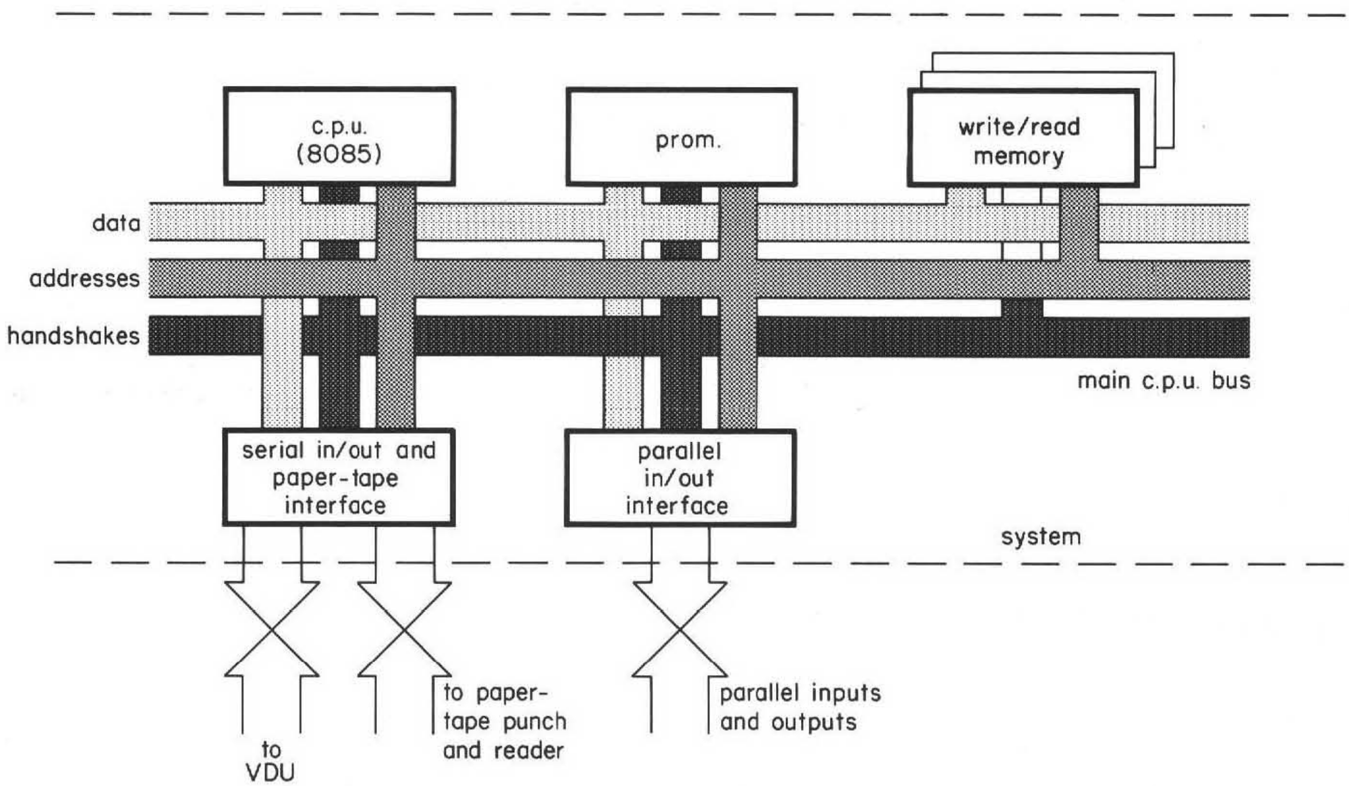


Fig. 2 — Microcomputer system arrangement.

controlling the units can be fed out to a printer.

The equipment is capable of operating with pictures derived from both 625 line, 50 Hz field frequency and 525 line, 60 Hz field frequency standards. In the following Section the equipment, as built at Research Department, is described in some detail. Initially the frame store, teletext transmitter and receiver were designed for 625 line, 50 Hz operation. The implemented modifications for conversion to the 525 line, 60 Hz standard are summarised in Appendix 9.1.

3. Equipment description

3.1. Microcomputer

An Intel 8085 microprocessor was chosen for the enhanced teletext experimental equipment because there was considerable experience at Research Department in its application and there exists reasonable documentation about it. In particular, a series of five 4U size BMM* printed circuit board designs forming a modular microcomputer based on the 8085 has been used successfully on BBC electronic graphics (Flair) apparatus†. A block diagram of their configuration around the computer bus is shown in Fig. 2. In its present form the bus can be extended to allow up to 16 input-output interface boards to be accomodated.

The basic system was improved for the present application to permit the use of a CP/M operating system and PASCAL capability. A new 4U board was designed to allow the CP/M system (purchased on a floppy disk) to be 'booted'‡ into the computer memory. This board has replaced the original 16K PROM board with a 2K bootstrap‡ PROM and 16K write/read memory making it possible to use the full 64K memory address capacity of the 8085. Experience gained to date has proved that this is worthwhile and the BBC electronic graphics apparatus has now been changed to operate in a similar manner.

* Binary Metric Module racking system used by the BBC.

† This was developed by N.E. Tanton.

‡ Following a computer 'reset' to program line 0, the first few program lines to be executed are held in a PROM and contain software which transfers the CP/M routines from disk to the microcomputer write/read memory. This process is called 'booting' and the PROM is called the 'bootstrap'.

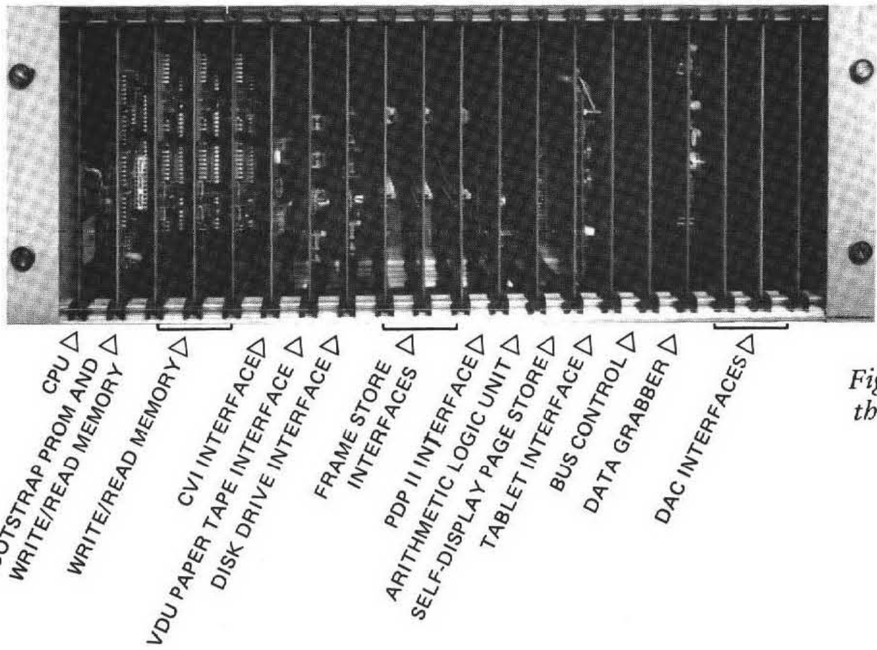


Fig. 3 – The microcomputer rack in the enhanced teletext experimental units.

The microcomputer rack in each unit of equipment is basically the same. Up to 20 boards can be accommodated as shown in Fig. 3, of which five comprise the 8085 and its associated memory. The remaining slots are used for the interfacing boards associated with peripheral devices such as v.d.u., frame buffer store, disk-drive, teletext data sender and teletext data grabber. The differences between the two units arise in the selection of peripheral devices which can be used.

3.2. Frame buffer store

A very economical basis for building video frame stores at the time of design was to use 16K dynamic write/read memories in the triple voltage version. The larger 64K memory devices were not then cost-effective for this application. Of the frame stores which had been designed and built at Research Department only one* was provided with the required separate multiplexed video and slow data-rate access ports. A frame store which can be sequentially scanned at the full video rate independently of the writing and reading of slow-rate video data to and from the microcomputer is needed to provide a continuous display of the frame store contents. In principle, this store* arrangement was acceptable and after some design modification it was chosen as the basis for the present store.

It was decided to allocate 24 bits to each picture sample and to dedicate them initially to 8 bits each for the (R), green (G), and blue (B) components. A data sampling rate of 13.5 MHz was chosen for the 625 line, 50 Hz field frequency standard (System I). This anticipated the CCIR recommended standard for digital interfaces in studios. The 'active' picture area contains 720 x 576 pixel locations and for 24 bits per location the minimum frame store capacity is found to be just over 1.2Mbyte (one byte is equivalent to 8 bits).

The frame store design adopted is based on a single bit-plane board containing 32, 16K write/read memory devices which is sufficient to hold 512K samples, 25% more capacity then the active frame of one colour component. Three such stores with 8 bit-planes each are, therefore, required to hold the R, G, B samples with the extra capacity available as auxiliary storage.

Each group of 8 bit-plane boards is interfaced to the microcomputer through control circuitry separated onto two boards as shown in Fig. 4. The board which connects directly to the computer bus (the X-Y controller) allows the frame store to be addressed at the operating rate of the microcomputer by two 10-bit numbers which identify a particular horizontal offset (X) and vertical offset (Y) and define X,Y co-ordinates of a displayed pixel. Slow-rate video data can be written to or read from the store via the data port independently of the full-rate video port; access to data and video ports alternates approximately every microsecond. The store can also be used simply as an extension to the computer memory, in which case a single 19-bit address is used and data can be retrieved within 2μs.

The timing of control signals and address

* Designed by N.E. Tanton.

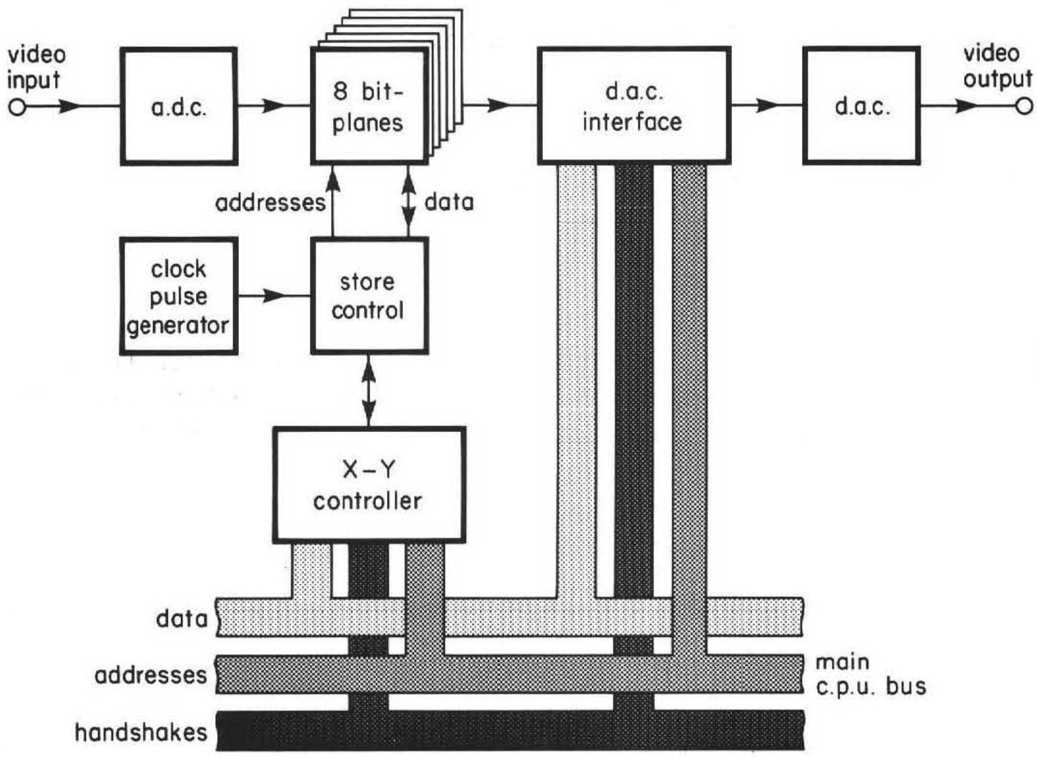


Fig. 4 – The frame buffer store arrangement.

generation is handled on the store control board which in common with the other two frame stores receives 13.5 MHz clock pulses and other field- and line-related pulses from a central clock-pulse generator board.

In the adopted design there is only one full-rate video port which is shared for video input and output. Video output generally takes precedence but single frames of video can be grabbed into the store by momentarily interrupting the video output for two field periods synchronised to the field synchronising interval. Each video input port requires its own analogue-to-digital converter (a.d.c.).

The video outputs are taken to their respective digitial-to-analogue converters (d.a.c.'s) via additional boards which also interface with the computer bus. These boards contain an array of write/read memories which can be programmed to allow simple video post-processing such as picture blanking.

The store is contained in an 8U BMM rack together with the associated a.d.c.'s and d.a.c.'s and is shown in Fig. 5. The three *X-Y* controller boards are housed in the microcomputer rack – see Fig. 3.

3.3. Teletext data sender (Computer video interface (CVI))

The teletext data sender is designed to produce a carefully timed teletext signal in non-composite video form (which can be added to a network output video signal for broadcasting).

The unit shown in the block diagram of Fig. 6 contains its own 8085 microcomputer system and an associated memory comprising a 32K PROM and a 32K write/read memory. Teletext "rows of data" are requested at a rate to match the output video synchronising pulses. Each row is stored in a memory buffer and when the buffer is full the request of further data rows is suspended. If no data is provided a test page of data is automatically selected from the PROM. This transfer of data is carried out to a well-defined protocol through a series of 'handshake' signals with the main computer. These are summarised in Appendix 9.2.

The output timing logic takes each data row from the buffer as required and assembles it with a clock run-in and framing code onto the appropriate line(s) in the field blanking period of the video waveform. Television line and data bit-rate counters are triggered from a mixed synchronising pulse to produce the required timing waveforms. Special provision is made for data transmission to be unimpeded by variable length television lines

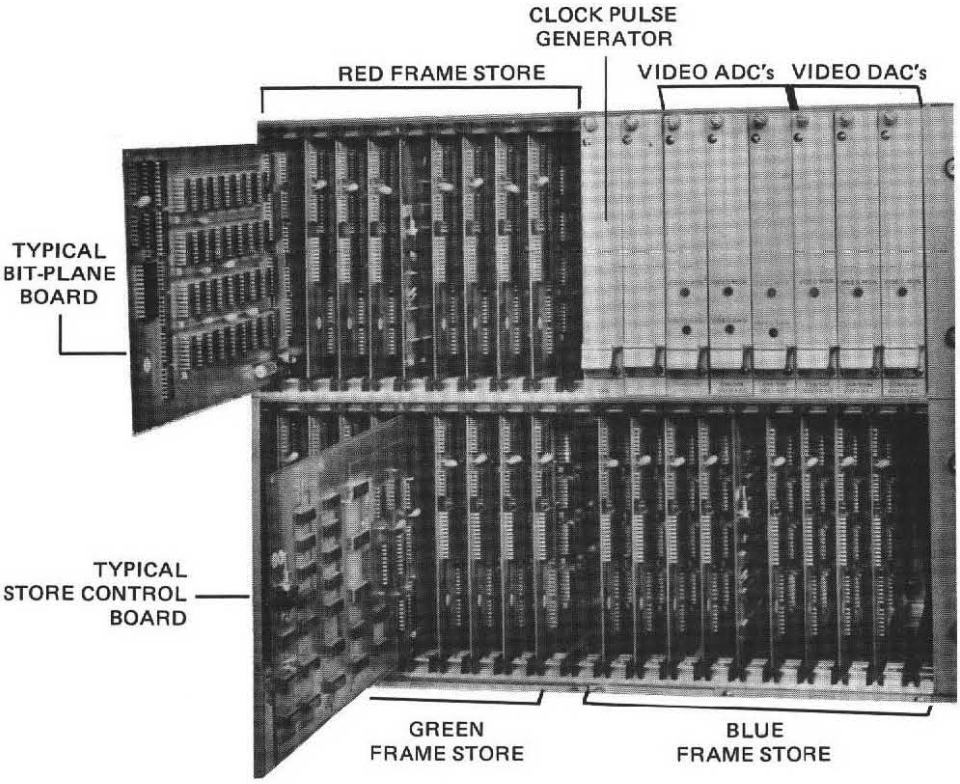


Fig. 5 – The frame buffer store as used in the enhanced teletext units.

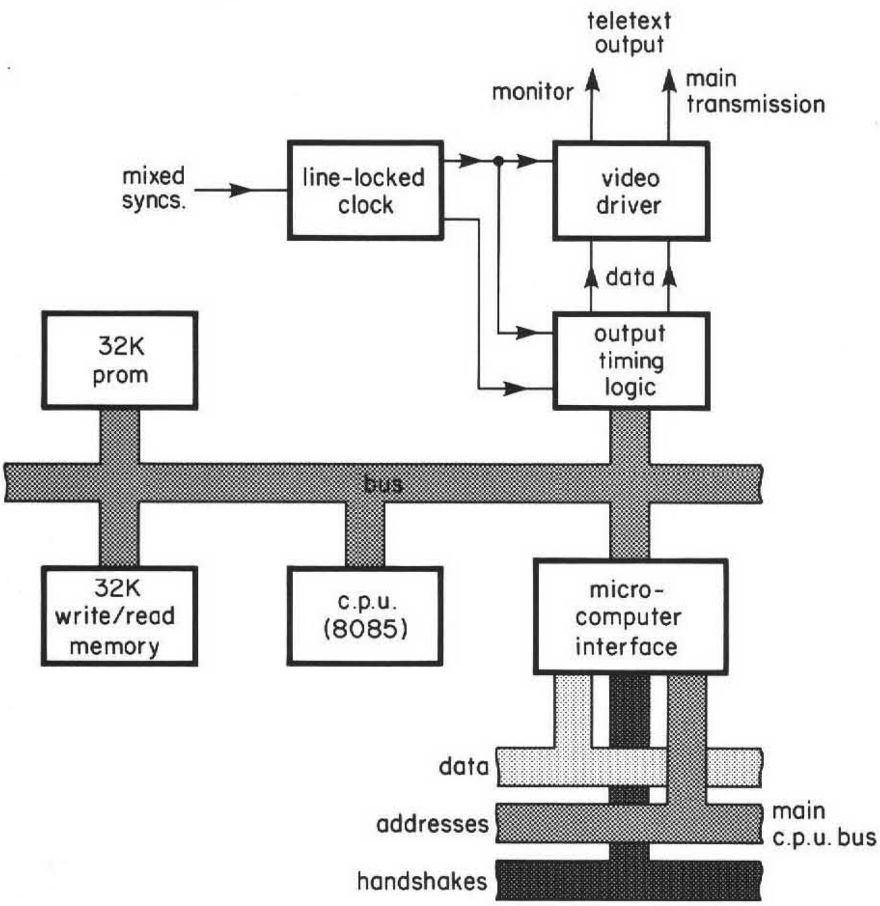


Fig. 6 – The teletext data sender arrangement.

and fields caused by television synchronisers and Genlock equipment. Non-synchronous cuts are also detected and data transmission is prevented until normal synchronisation is restored. Two outputs are produced; the first one, intended for the main transmission, is advanced in time to allow for delays in subsequent amplifiers and filters prior to transmission. The second output is timed directly to the incoming mixed synchronising pulses and is used for monitoring purposes.

The video driver contains suitable pulse-shaping and filtering to optimise the reception of data at a receiver. Particular care has been taken to ensure that the output waveform is symmetrical with respect to zeros and ones, and free from any timing jitter or intermodulation effects caused by cross-coupling from the logic circuits. The teletext data sender is self-contained in a 4U rack with its own power supplies and function indicating lamps and is shown in Fig. 7.

device to form the characters from the teletext data. Known as a self-display page store, G E C type M41-4, it can be interfaced to the micro-computer bus and treated as if part of the system memory. Video *R*, *G* and *B* signals together with synchronisation pulses are automatically generated allowing the contents of the page store to be displayed as a teletext page on a 625-line picture monitor. The self display page store as constructed is illustrated in Fig. 10.

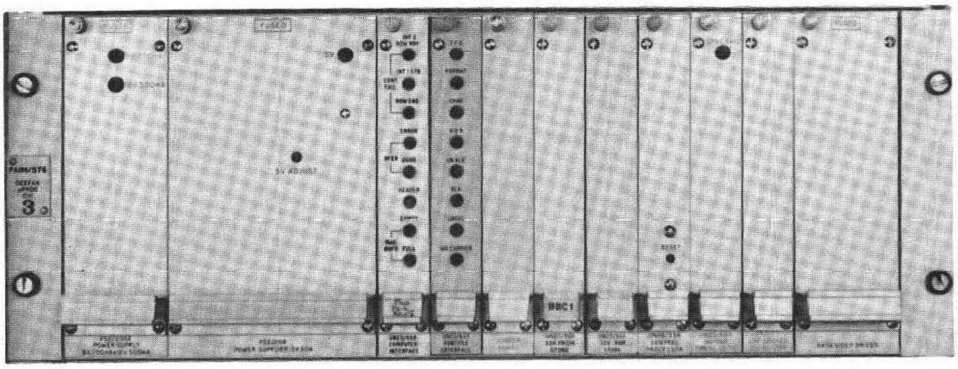


Fig. 7 — The teletext data sender.

3.4. Data grabber

The data grabber design is made up on commerically available l.s.i. timing and acquisition chips and uses a single 4U printed circuit board. A block diagram is shown in Fig. 8 and Fig. 9 is a photograph of the board as built. Serial data and timing information are recovered from the video with teletext input signal by the set of three timing and data acquisition circuits. Parallel conversion of the data is performed and the parallel data is supplied to the framing code detector. Correct reception of the framing code during a prescribed time window starts the bit and acquisition address counters and loads the row of teletext which follows into the buffer store. Communication with the microcomputer is inhibited during the data-entry period.

During the active television field period the microcomputer interface scans the buffer store for new data, reads it, blocks out the stored framing code to acknowledge receipt of each row and supplies it to the microcomputer memory.

Another data receiver suitable for acquiring the Prestel videotex transmissions using a chip set supplied by Mullard, has also been provided.

3.5. A self-display page store

In the initial phase of the work, pages of teletext could be directly displayed on the picture monitor by using another commercially available

3.6. Floppy disk system

The disk-drive chosen is a Remex type RFS 4810/20 dual, double-sided double density system operating with standard 8" floppy disks. Each disk has a capacity of just over 1.2M byte which is sufficient to hold one full-resolution, *R*, *G*, *B*, 13.5 MHz sampled active television picture. The disk drive contains its own microcomputer control and is interfaced to the main microcomputer through 15 control lines. Eight of these are bidirectional, transfering data, status, disk address and other control information and the remaining seven control the handshake process.

The data block transfer, disk formatting and sector sizing are, therefore, all automatic. Data can be transferred between the microcomputer and a disk drive at approximately 35 kbit/sec.

3.7. Mechanical considerations

Each of the two enhanced teletext experimental units is housed in a single bay as illustrated in Fig. 11. Apart from the teletext data sender, which is a self-contained rack, the other racks derive their d.c. power from a collection of switched-mode power supplies situated in the lowest rack. D.C. power at +5V, −5V, +12V and −12V is distributed by connectors and multi-way leads as required. All racks are, therefore, individually demountable. Cooling is provided by a single centrifugal fan unit located at the bottom of each bay. The total power consumption is

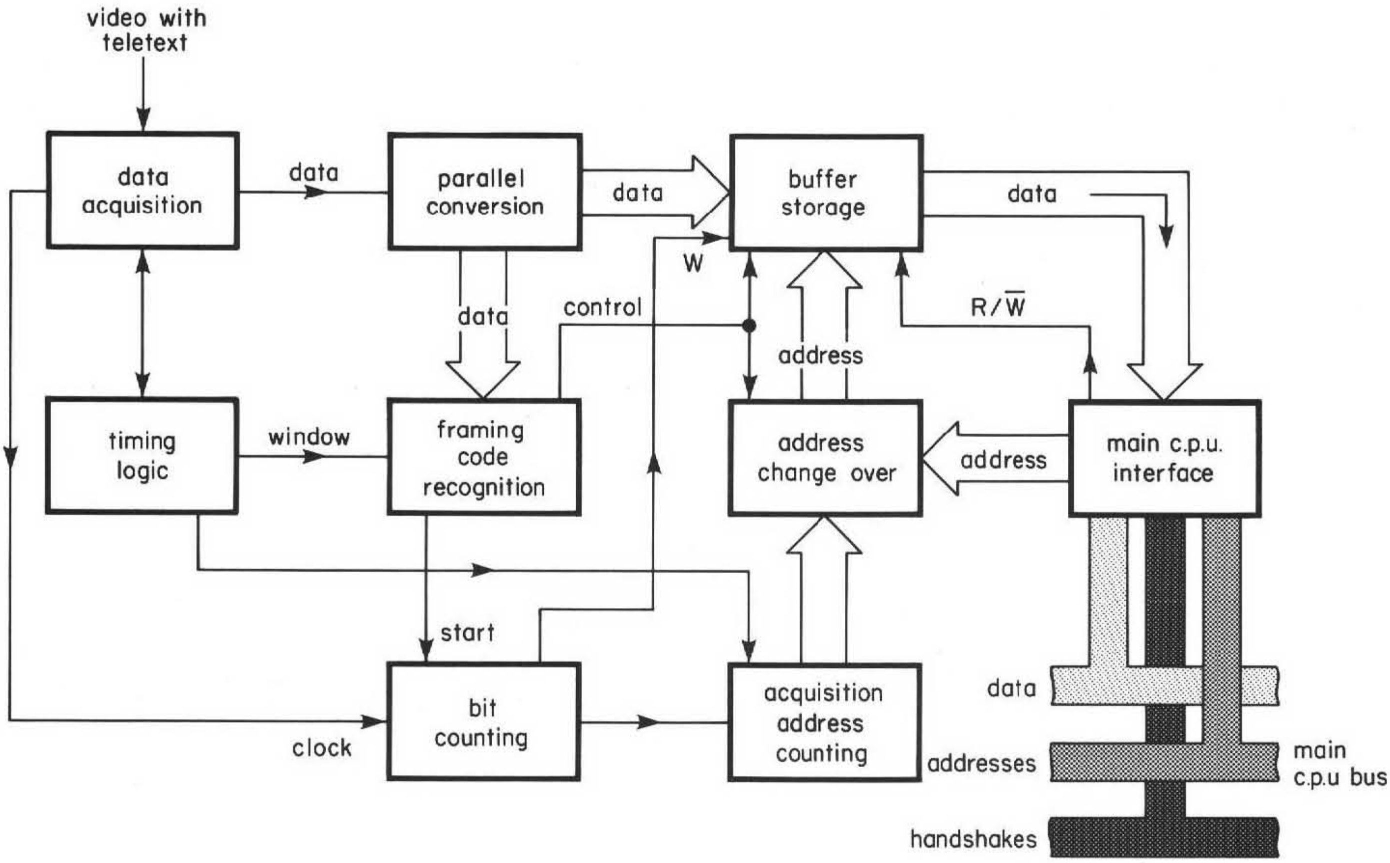


Fig. 8 — The teletext data grabber arrangement.

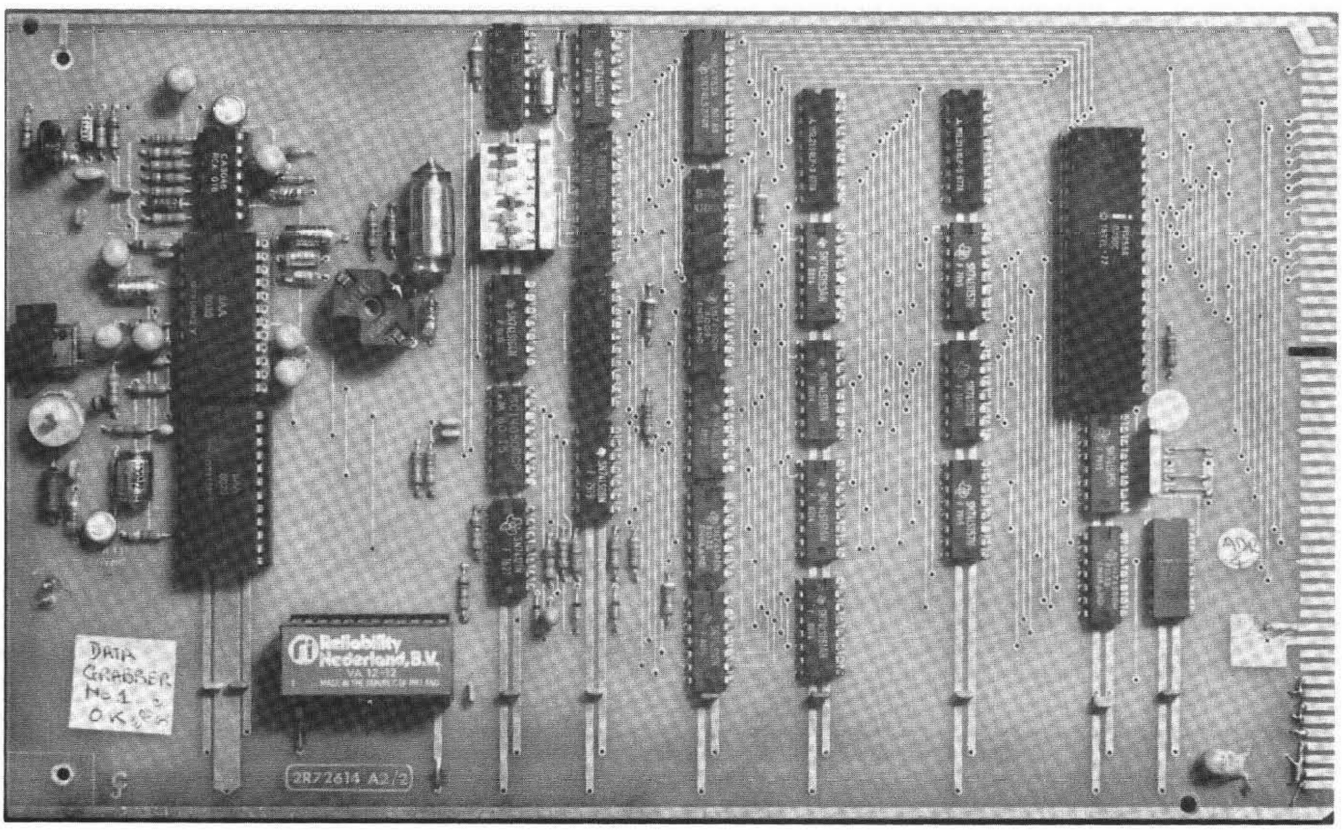


Fig. 9 — The teletext data grabber.

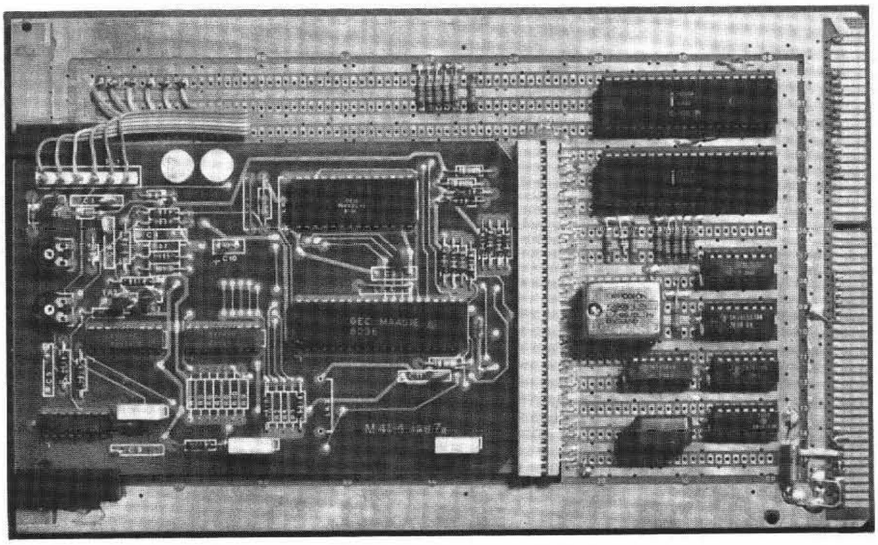


Fig. 10 – The self-display page store.

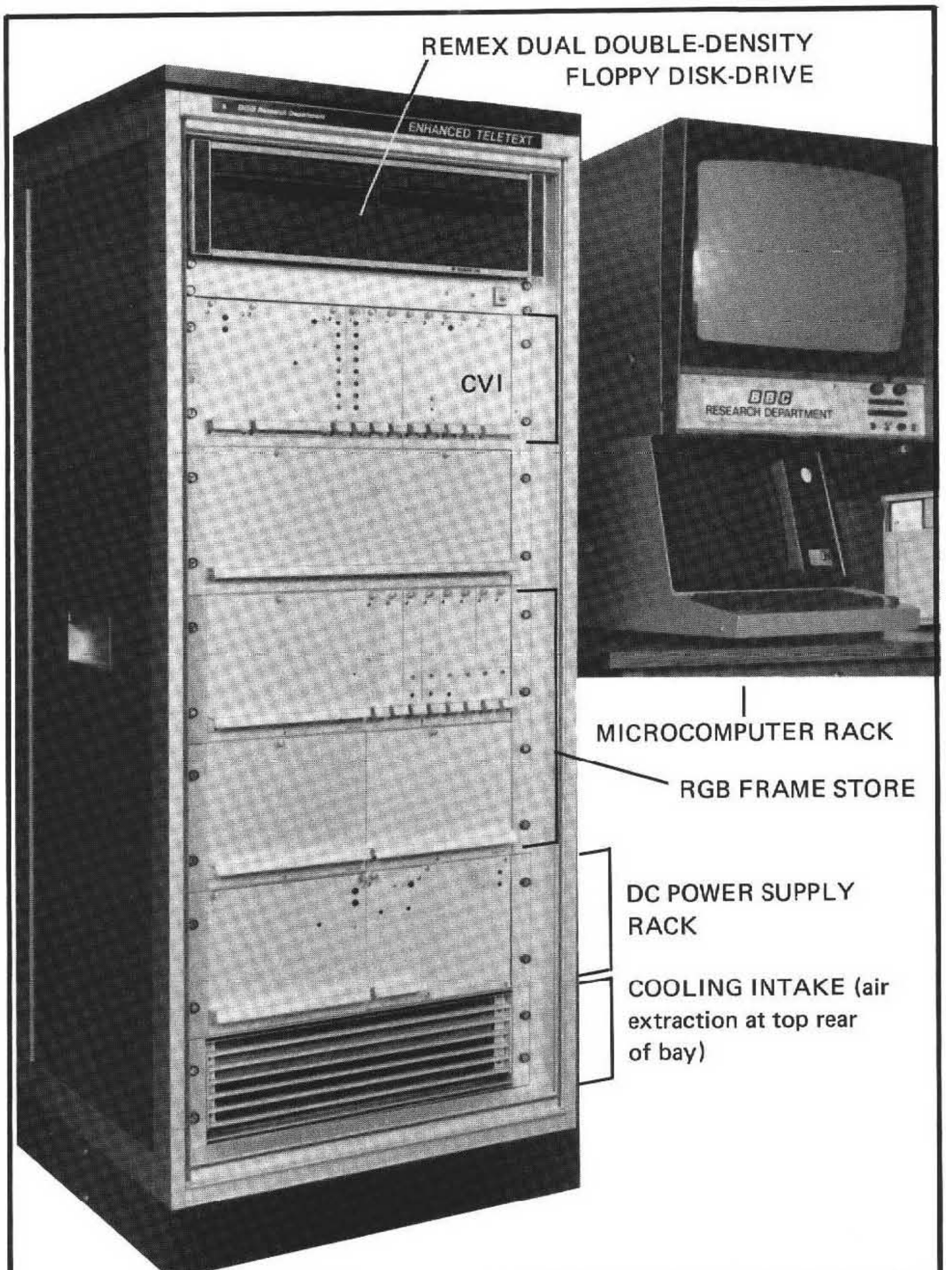


Fig. 11 – One of the enhanced teletext experimental units with its associated v.d.u. and picture monitor for displaying contents of the frame store.

1 kW maximum per bay.

4. Software development

4.1. General

Software development has been greatly simplified by the use of the CP/M operating system and the preparation of programs in PASCAL. For a modest sum (currently less than £100) a package of software can be bought on a floppy disk which contains not only the operating system but also an editor, 8085 assembler and debugging routines. The cost includes a licence to use the software on a particular equipment. It is also backed up by thorough documentation. Basically the operating system enables named files to be used efficiently and the microcomputer function to be controlled by simple v.d.u. keyboard commands. One part of the CP/M software contains the hardware-dependent routines which require modification to suit particular peripheral devices e.g. disk drive and line printer.

The loading of the CP/M routines from floppy disk into system memory is repeated each time the equipment is used. A small 'bootstrap' ROM (currently 2k bytes) contains a brief routine which automatically loads the leading CP/M routines from disk into write/read memory. These routines take over from the ROM which is automatically switched out making the full write/read 64K memory available to the CP/M system. The bootstrap routine is very short and there is sufficient room in the PROM to hold a 'monitor' program which is useful for examination of memory contents and for keyboard editing.

Using the CP/M text editor, experimental programs can be prepared in PASCAL, compiled and run entirely within the teletext equipment. The option of downloading assembled programs from another computer (a PDP 11 was used initially) is, however, still open.

4.2. Conventional teletext

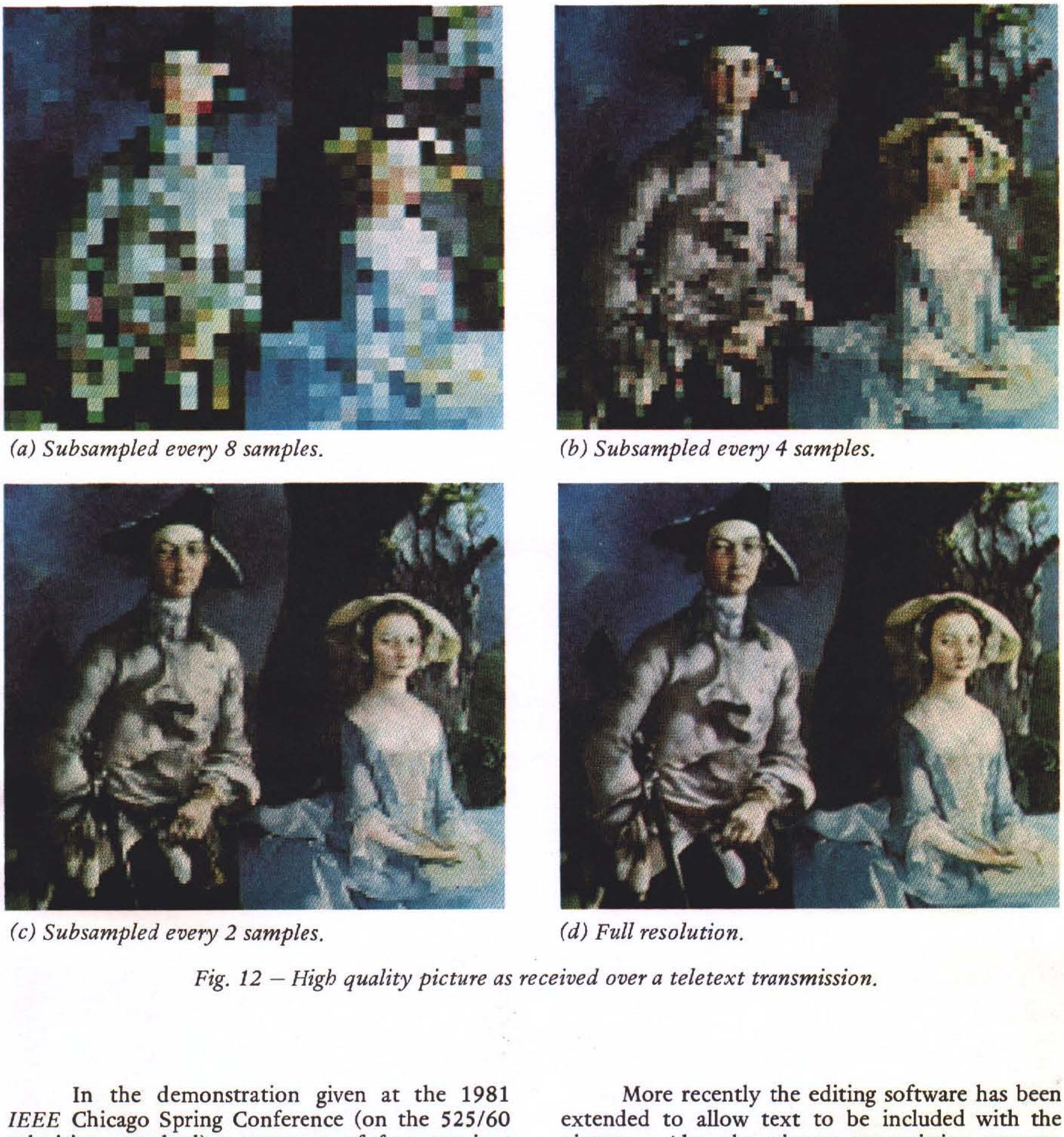
One of the first areas to be explored was the capture of currently broadcast teletext pages and the generation and editing of new pages. In the editing mode a cursor can be moved at will on a monitor display and all the conventional teletext characters and mosaic graphics symbols can be used.

Recently the broadcast Ceefax service has been extended to include "linked" page facilities [1] and information about the television network on which the teletext service is carried. Extra data is sent with each page to specify several (currently up to six) addresses of pages which the editor chooses on the basis of what he considers the viewer is likely to want to see next. An intelligent receiver equipped with storage for several teletext pages can automatically acquire the linked pages and hold them for instant access. A software package has been produced to allow the enhanced teletext equipment to respond to these signals. Besides linked page addresses a check word is also sent with each page to enable a receiver to compare its value with its own calculation of the check word and hence signal a correct reception of a page.

4.3. Slow-scan television

The second area of interest was to show that high-quality pictures can be transmitted over the teletext system i.e. slow-scan television. In the transmitter an *RGB* video frame can be 'grabbed' into the frame buffer and displayed on the picture monitor. Because of the propagation delay through the a.d.c. and frame store control circuits, the image is input in a position which is delayed relative to the synchronising pulses applied to the monitor. A simple software routine is invoked to advance the picture and restore its normal relationship with line synchronising pulses. The picture can be stored on disk and retrieved - an operation which takes about five minutes each way for a full-screen image. A picture editing routine can be used to draw an imaginary "frame" around a chosen part of the picture and to position it at will within the teletext page area. Again, simple commands from the keyboard control the picture transmission routines which code the picture data into manageable blocks of data prior to it arriving at the teletext sender. The investigation of the means for optimising this coding is referred to later and could form a major part of the future work in this area.

At the receiver, another set of routines is needed to prime the teletext data grabber, decode the data and display the teletext page on the receiver picture monitor. Using two data lines per field on the 625 line system (corresponding to 32 kbit/s) a full-screen picture takes about 5½ minutes to transmit. This, of course, bears little relation to the time it might eventually take for a similar image to be transmitted if work to reduce the bit-rate and implement sophisticated coding techniques is done. It is not unreasonable to anticipate a factor of ten in the reduction of transmission times of pictures via teletext.



(a) *Subsampled every 8 samples.*

(b) *Subsampled every 4 samples.*

(c) *Subsampled every 2 samples.*

(d) *Full resolution.*

Fig. 12 – High quality picture as received over a teletext transmission.

In the demonstration given at the 1981 *IEEE* Chicago Spring Conference (on the 525/60 television standard) a sequence of four routines was automatically cycled. The first three routines transmitted a subsampled version of the picture which were, in the order of transmission, every 8th sample, every 4th sample and every other sample respectively in both horizontal and vertical directions. The cycle was completed by transmitting the full resolution picture. In this way the first image appeared in 1/64 of the total transmission time and the resolution was gradually built up with succeeding scans. Examples of the frames transmitted are shown in Fig. 12 (a), (b), (c) and (d).

More recently the editing software has been extended to allow text to be included with the picture. Also the picture transmission arrangements are now such that effectively the stages shown in Fig. 12 (a) and (b) are omitted; the first picture to be visible is similar to that shown in Fig. 12 (c).

4.4. Improved characters

The 1976 Teletext Specification[2] makes no recommendation about the display of individual characters and different decoder manufacturers have tried a number of techniques to improve their legibility. A further improvement can be

gained by moving towards higher resolution characters based on a full matrix of sample points, each with a limited grey-scale, and appropriate output filters. This would permit a much wider range of character styles to be used than at present. Different fonts could be used, at the discretion of the editor, to improve the aesthetic quality of the teletext page or it may be left to the decoder manufacturer to choose the font he prefers.

Routines have been established for retrieving digitised character data from disk as supplied by the Monotype Corporation. After suitable filtering and gamma correction the character data are transferred to the auxiliary part of the receiver frame store in an initialisation process. During the reception of normal broadcast transmissions the improved decoder interprets a 7-bit character code as a high-resolution rendering of that character by using the previously processed data held in the receiver frame store. A typical teletext page displayed with the character set of the improved decoder (in this case Gill Sans) is shown in Fig. 13 (a): the same page using a conventional decoder is shown in Fig. 13 (b) for comparison. This was first publicly demonstrated at the Berlin Radio Show in September 1981. The speed at which a page builds up with the well-formed characters would be comparable with existing decoders although the speed of the demonstration equipment is currently limited by software processing time.

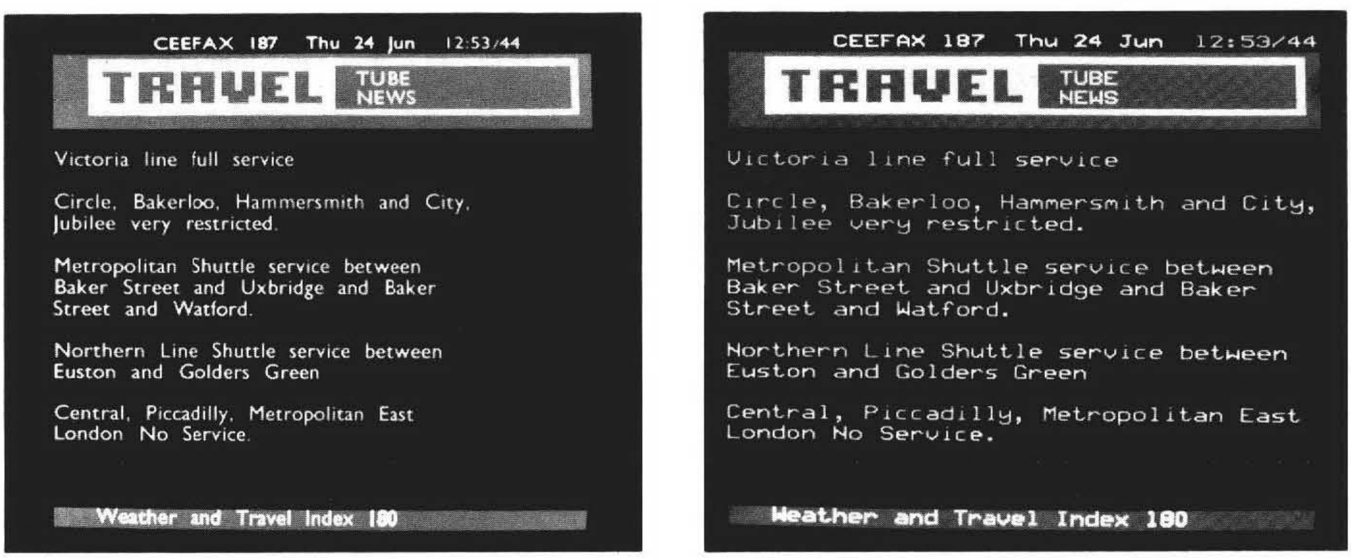
To accord with the CEPT European standard[3] and for instrumental convenience, the enhanced display width has been set at 480 pixels which allows 12 pixels per character, as in the CEPT standard.

This overall width is narrower than that conventionally displayed, being about two thirds of the active line period at this sampling frequency. There is no fundamental reason why the enhanced display width should not be the same as that of a conventional display.

5. Potential uses of the equipment

5.1. Geometric drawing

The description of an image in terms of basic geometric shapes and colours can lead to a much improved graphic display for a relatively small increase in decoder storage when compared with that required for high-quality pictures. There has been a considerable development in this technique already in connection with BBC electronic graphics work and this area is currently being studied elsewhere[4]. One of the features of the Research Department work so far has been the elimination of the jagged edges so often associated with electronic graphics on a television screen. This is particularly noticeable on near horizontal lines where there would normally be a "stepped" effect because of the television line structure. The effect is illustrated in Fig. 14 (a) and (b). In this case the full 8-bit grey scale has been used to provide the appropriate "shape" to the profile of the lines. This treatment can be applied to any mixture of foreground and background colours. A limited range of the other facilities offered by the BBC electronic graphics equipment may also be incorporated to allow "painting by numbers"



(a) *(b)*

Fig. 13 — Comparison of character displays.
(a) Improved font. (b) Conventional dot matrix.

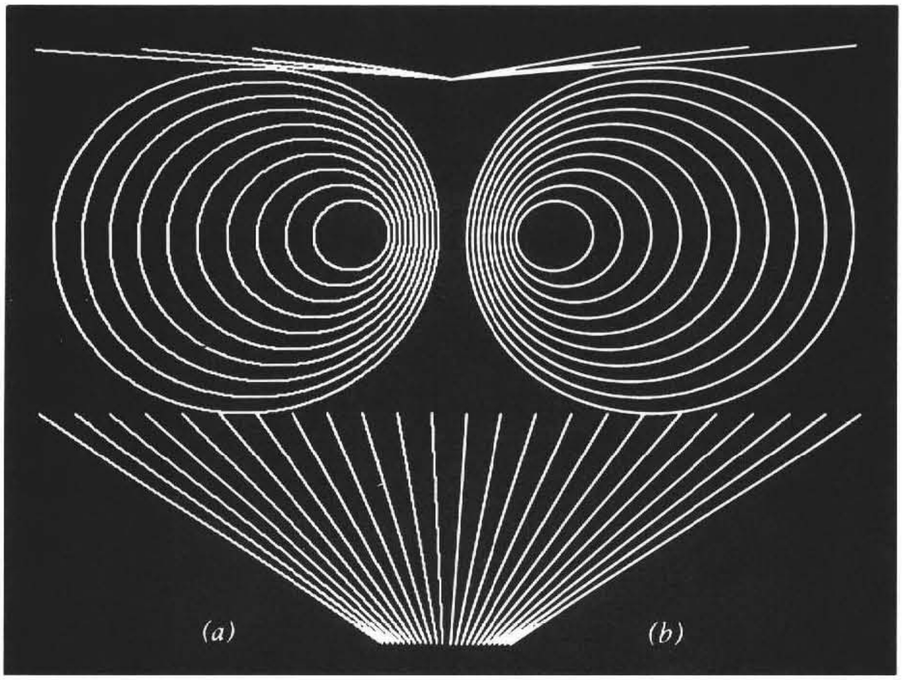


Fig. 14 – A geometric primitive display.

(a) With jagged edges.

(b) Without jagged edges.

and "cut-and-paste" techniques to be used.

5.2. High quality picture coding

The first attempts to show that picture teletext was possible[5] were made without considering the need to reduce the amount of data necessary to define the picture. *R*, *G* and *B* samples were sent at a 13.5 MHz sampling rate making a total frame capacity of about 1.2Mbyte.

Whereas the choice of 13.5 MHz for the data sampling rate is strengthened by its acceptance as an International digital television standard for studio use, it does not necessarily follow that this must be accepted as the standard for picture teletext/videotex. Indeed a much lower sampling frequency and different sampling structure may be perfectly acceptable and perhaps necessary to establish a standard to which British broadcasters and other users, such as British Telecom, can agree. There may be some benefit in choosing a sampling structure based on the 13.5 MHz standard: for instance, one suggestion is that a $10\frac{1}{8}$ ($13.5 \times \frac{3}{4}$) sampled luminance and $3\frac{3}{8}$ ($13.5 \times \frac{1}{4}$) sampled chrominance components on alternate television lines would be a possibility.

There are fundamental differences between the source-signal of teletext pictures and normal television pictures. The teletext source-signal is static: the odd and even fields are fully correlated so that the pre-coding of the picture can be optimised well before transmission and the code sent as part of the transmitted data. The coder can, therefore, be relatively complicated compared with the decoder which can be kept simple. Also, all the parts of the picture are always available – so that the coding need not be based only on previous samples from the present and foregoing television lines. The overall picture can be assessed before deciding which code to use for transmission. For example, differential pulse-code modulation techniques may be used in some circumstances, based on a complete low-accuracy picture sent previously.

Transform coding has been the subject of earlier Research Department Reports [6,7] and could form another basis for future work directed towards picture teletext coding.

There is an essential difference between the coding required for videotex and for teletext pictures. In the former case the data is sent on request and the coding can, therefore, provide for a slow build-up of picture resolution by sending the different versions in turn. In the teletext case, picture transmissions may be required to be continuously repeated in the same way as most teletext pages and a special "polyphase" coding technique will be required to allow the lowest resolution image to be extracted from the full resolution image regardless of when the image was selected.

5.3. Broadcast software

One method of distributing software to people who have microcomputers is through

broadcasting software by teletext, sometimes known as telesoftware. A teletext adapter has been developed by Acorn Computers Ltd., based on a Research Department design, as part of the B.B.C. Microcomputer System and a series of transmission instructions (protocols) has been defined for this application.

As a means of keeping in touch with developments in this area and possibly making recommendations for improvement or standardisation it will be possible to adapt the enhanced teletext equipment to simulate a teletext adapter. By adding an interface to a B.B.C. Microcomputer (shown in Fig. 15) and with appropriate software, telesoftware can be received.

demonstrated at home and abroad on both the 625/50 and 525/60 television standards. An improved decoder has been created incorporating a store of well-formed typographical characters to enhance the readability and appearance of text, with a multi-page store to respond to the currently broadcast "enhanced" Ceefax signals. Consideration is being given to further work on other teletext enhancements.

7. Acknowledgement

The software for the work described in this Report was developed mainly by D.J. Rayers. Some of the work was partially funded by the Department of Industry.

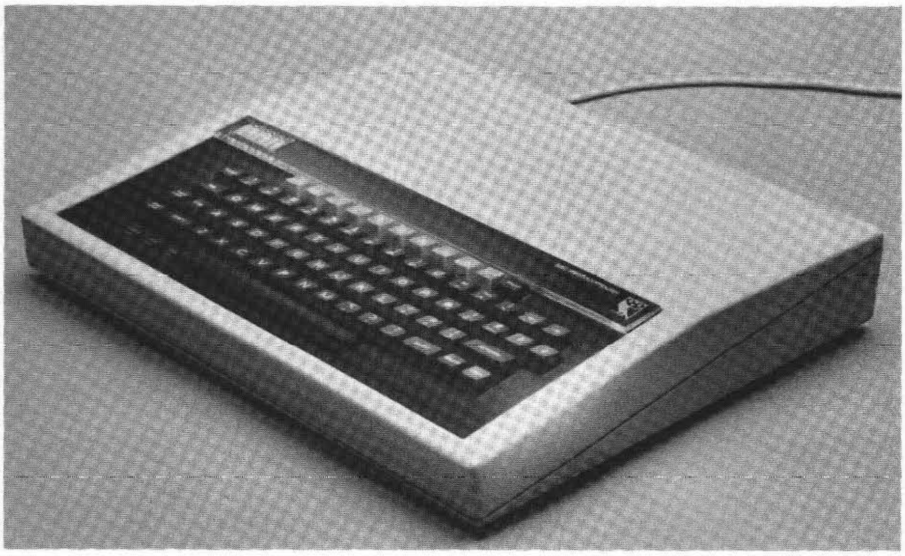


Fig. 15
The BBC Microcomputer

6. Conclusions

A pair of almost identical bays of experimental equipment has been assembled for the purpose of investigating several aspects of enhanced UK teletext, such as improved access to pages, better typography, improved graphics and high-quality picture teletext. Each bay constitutes an enhanced teletext sending or receiving terminal and each contains its own microcomputer system, frame buffer store, which is capable of displaying any image (with a resolution limited only by the scanning standard), and other peripherals. A computer operating system has been implemented which has greatly simplified the production of experimental software routines. The PASCAL language has been used in the work so far to develop routines for grabbing, generating, editing, storing and transmitting and receiving teletext pages of the kind currently broadcast. Further routines allow a high-quality full-screen picture to be coded and transmitted over the teletext system. This operation has been successfully

8. References

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(Appendices overleaf)

9. Appendices

9.1. Modifications to the experimental equipment for 525/60 television standard working

For the demonstrations of enhanced UK teletext on the North American 525/60 television standard (System M) a number of modifications were made to some of the equipment which has been described. The changes concerned the following:-

(a) teletext data generator.

- change of clock rate to 5.7272 MHz ($364f_H$).
- change of television waveform timings.
- data shaping filter scaled to changed clock rate.
- low-pass filtering of transmission output reduced to 4.2 MHz.
- minor changes in the software reducing the number of data bytes transferred per row from 45 to 37.

(b) teletext receiver.

- a different commerically available timing and data acquisition chip operating on System M was used.

(c) Frame store clock pulse generator.

- change in data sampling to 11.4545 MHz ($728f_H$).

(d) Frame store control.

- reduce the number of samples stored per active television line to 606.
- reduce the number of television lines stored to 485.

9.2. COMMUNICATION BETWEEN COMPUTER AND CVI

COMPUTER-VIDEO INTERFACE C.V.I.		16 BIT I/O MODULE OF C.P.U.
If ROW READY or DATA STROBE do not appear within 50 ms and the CVI is not in the output mode INT2 pulses are sent at 50 ms intervals until a response is obtained. (This ensures a satisfactory start up of the transfer routine)		
INT2 is a request to the computer to set up a row of CEEFAX data (a block of 21 x 16 bit words) ready for transfer. It is normally sent as soon as the previous row transfer has been completed.	INT2	On receipt of INT2 the computer sets up an output routine for 1 row of CEEFAX data. If REQUEST NEW ROW has been set to '0' the next row is prepared, but if it remains at '1' data for the old row is retained for re-transmission.
Receipt of a ROW READY pulse sets a latch in the CVI and cancels any low condition of the REQUEST NEW ROW LINE.	ROW READY	When a row is ready for transmission ROW READY is sent.
When the CVI is in the data input mode and the ROW READY latch has been set, INT1 is sent to the computer to request transfer of the first 16 bit word.	INT1	On receipt of the first INT1 pulse the computer transmits the first 16 bit data word of the CEEFAX row. The DATA STROBE is sent to indicate that the data lines are stable and ready for interrogation.
Further INT1s are sent to transfer each of the remaining 20 data words. The second to 21st are initiated by receipt of the 1st – 20th data strobes respectively.		Subsequent INT1 pulses cause subsequent data words to be transmitted. The computer keeps a tally of how many words have been sent.
Receipt of a data strobe pulse causes the data on the data lines to be clocked into the store. The store character pair address is then incremented.	DATA STROBE	
Receipt of the 1st – 20th DATA STROBE initiates a further INT1 pulse.		
The 21st DATA STROBE triggers a 'TIME-OUT' circuit which awaits a row end pulse.		When the computer thinks that 21 words have been transmitter ROW END is sent soon after the last DATA STROBE.
The TIME-OUT circuit dictates that ROW END must arrive within 2·0 ms following the 21st data strobe. If it arrives before or after this time a transfer error is assumed. If a spurious 22nd DATA-STROBE should arrive before the ROW END pulse the TIME-OUT 2·0 ms delay is cancelled and this causes an assumed transfer error.	ROW END	
Receipt of a ROW END pulse or cancellation or expiry of the TIME-OUT period initiates an INT2 pulse.		
If the ROW END pulse arrived within the TIME OUT period REQUEST NEW ROW is set low, otherwise it remains high. (The computer will interrogate the REQUEST NEW ROW line when it receives an INT2 pulse).	REQUEST NEW ROW (old / new)	This is interrogated by computer when an INT2 pulse is received. It must be in the correct condition from the start of the INT2 pulse until ROW READY is sent.
REQUEST NEW ROW is reset to the high condition by receipt of the ROW READY pulse. In this way if further INT2 pulses are sent because of a lack of response from the computer the request for a new row will be repeated if ROW READY has not been received. Once ROW READY is sent a new row is considered by the computer as an old row. Using ROW READY to reset the state of the REQUEST NEW ROW line ensures that any repeated request is in the correct form.		

Printed by BBC RESEARCH DEPARTMENT, Kingswood Warren, Tadworth, Surrey, KT20 6NP